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**SHELF LIFE OF SLICED BACON:
SENSORY QUALITY OF COMMERCIAL
TYPE WITH LIQUID SMOKE VERSUS
MILITARY TYPE WITH HARDWOOD
SMOKE**

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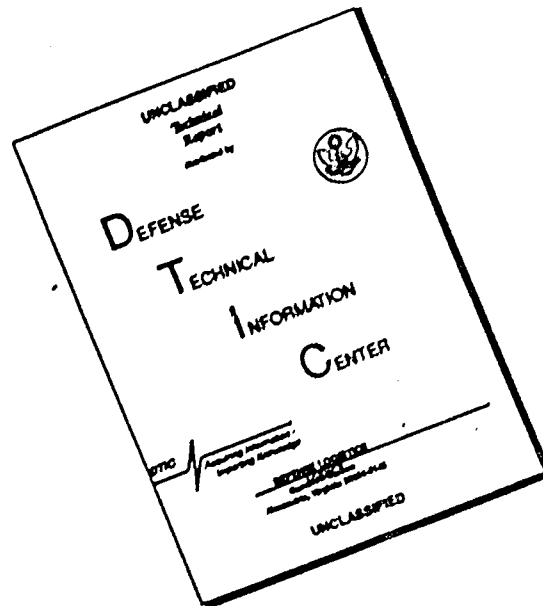
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The storage stability of sliced bacon, produced either with liquid smoke or with hardwood smoke and packed under vacuum or under air and stored for 48 weeks at -18°C, was evaluated for odor and flavor quality by a trained sensory panel of 12-18 technical personnel. With respect to odor and flavor, liquid smoke/vacuum packed bacon retained acceptable quality through 48 weeks of storage; liquid smoke/air-packed bacon through 40 weeks, and hardwood smoke/vacuum-packed bacon through 28 weeks. Hardwood smoke/air-packed bacon showed significant (one percent level) loss in both odor		

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Abstract (continued)

and flavor quality by the twentieth week of storage. Least squares analysis confirmed that the flavor and odor ratings of the liquid smoke/vacuum-packed bacon samples changed the least over the 48-week storage period.

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PREFACE

These investigations were conducted to compare, through sensory panel evaluation of odor and flavor, the storage stability of sliced bacon treated with liquid smoke or with hardwood smoke, and packaged under vacuum or in an atmosphere of air. The product, so packaged, was evaluated for odor and flavor quality during storage at -18°C (0°F) for a period of 48 weeks using withdrawal at 4-week intervals.

This effort was undertaken under the project, Production Engineering in Support of the DoD Food Program, Army Management Structure Code 728012.19000, task entitled "A and B Ration."

The authors gratefully acknowledge the contributions of Raymond Mansur, Food Packaging Group, for technical assistance in packaging. The interest and support of the sensory panel in providing the sensory data reported herein are appreciated.

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SHELF LIFE OF SLICED BACON: SENSORY QUALITY OF COMMERCIAL-TYPE WITH LIQUID SMOKE VS. MILITARY-TYPE WITH HARDWOOD SMOKE

INTRODUCTION

The traditional method for producing smoked flavor in bacon has involved the use of a hardwood smoking process, and sliced bacon procured by the Military Services has been processed in this manner. Military Specification PP-B-81G Bacon, Slab or Sliced, Chilled or Frozen, requires that this smoking process be employed.¹ Because of public health considerations associated with increasing industrial atmospheric pollution, legislation by federal and municipal authorities has restricted the amount of pollutants that can be emitted by an individual processor, especially in highly populated areas. Suppliers of bacon for the Military in certain parts of the country are affected by these regulations and have requested relief from the use of the natural hardwood smoke process. Commercial manufacturers of bacon products have been achieving an acceptable smoked flavor by using a liquid smoke process successfully for several years.

Since long-term storage stability information for liquid smoked bacon is not available, this study was initiated to assess the odor and flavor quality of this product in comparison with hardwood smoked bacon over a storage period of 48 weeks at -18°C (0°F). The Military supply system for bacon depends on extended frozen storage life, in contrast to commercial marketing, which depends on short-term storage. The PP-B-81G specification and commercial packaging have a common requirement for vacuum packaging. This study included an evaluation of air packaging compared with vacuum packaging in long-term storage, as air packaging would reduce the procurement cost. Mylar-type film, which is impermeable to oxygen, was used for both the air and vacuum packaging.

MATERIALS AND METHODS

Materials.

The bacon evaluated in this study consisted of bulk sliced bacon (18-22 slices per lb) that was freshly manufactured and shipped to the US Army Natick Research and Development Center by Blue Bird Foods, Inc., Chicago, IL. The lots received were of two different smoking treatments: (1) slices prepared from slabs that were "smoked" using a liquid smoke (LS) and (2) slices prepared from slabs that were smoked in the traditional manner, using hardwood smoking (HS) procedures customary for Military contracts. Otherwise, the smoked bacon in each case was produced in accordance with Military Specification PP-B-81G Bacon, Slab or Sliced, Chilled or Frozen. The sliced bacon from each smoking treatment was packaged by shingling on greaseproof paperboards with slices placed parallel to the long axis of the board. The paperboards were placed in Mylar bags (polyethylene-terephthalate-polyethylene film). Half of each smoke-treated lot was then closed under approximately 25 inches of vacuum (VAC) and heat-sealed. The remaining half was heat-sealed without vacuum (AIR). All samples were stored at -18°C and were evaluated for odor and flavor at four-week intervals over a period of forty-eight weeks.

Preparation.

All samples for sensory evaluation were prepared by the Animal Products Branch, Food Engineering Laboratory, and delivered immediately to the Experimental Kitchens Branch for sensory panel testing. The bacon was prepared according to Armed Forces Recipe Card L-2, Change 4, for Baked Bacon Slices. The preparation end point was determined visually on the basis of crispness due to the variable ratio of fat to lean in the bacon.

Sensory Panel Evaluations.

All sensory evaluations were conducted by the Experimental Kitchens Branch, Food Engineering Laboratory, using a technical panel of 12 to 18 personnel. The panelists were selected from a group of 24 persons screened for their ability to discriminate and reproduce results in a test on bacon. Panel sessions began as soon as the prepared bacon was received from the Animal Products Branch. All cooked samples were held for serving in paper-towel-lined serving pans in a 71°C (160°F) bain-marie and were served on prewarmed plates. At each session, each panelist was served a total of 4 samples (one sample from each treatment lot) simultaneously; samples were served in a balanced, random, nonsequential order. Serving size was half a slice of cooked bacon. Panelists were asked to evaluate only the attributes of odor and flavor quality, using the Food Quality Evaluation Form, STSNL Form 964 (Figure 1) and labeled as "Bacon." The test form uses a 9-point rating scale for each quality attribute from 1 (extremely poor) to 9 (excellent), and encourages the panelist to be as descriptive as possible by allowing space for comments to indicate the basis for the rating. Ratings in the range of 1 to 4 indicate that the attribute does not meet the quality standard. Ratings in the 5 range show the attribute is borderline in quality. Ratings in the range of 6 to 9 indicate the attribute meets the quality standard. Water for mouth rinsing and unsalted crackers were furnished to reduce flavor carry-over between samples.

Data Analysis.

Sensory panel data for odor and for flavor were analyzed separately using analysis of variance to evaluate main effects of storage time (0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, and 48 weeks). The Duncan Multiple Range Test was run to determine where significant differences occurred.² All significant differences in this study are reported at the 5% or 1% level of significance. Regression analyses were also performed on the mean odor and flavor ratings to evaluate the effects of treatment (commercial liquid-smoke process vs military hardwood-smoke process) and of packaging (air-packed vs vacuum-packed).

TABLE 1. Mean sensory panel ratings for odor and flavor of sliced bacon produced with hardwood smoke (MS) or liquid smoke (LS) and vacuum or air packed, evaluated at 4 week intervals over 48 weeks of storage at 0°F (18°C)

STORAGE PERIOD (wks)	ODOR				FLAVOR			
	MS		LS		MS		LS	
	VAC	AIR	VAC	AIR	VAC	AIR	VAC	AIR
	RATING	Sig. RATING	RATING	Sig. RATING	RATING	Sig. RATING	RATING	Sig. RATING
	initial	initial	initial	initial	initial	initial	initial	initial
2	15 7.0	6.5	6.8	6.9	6.9	5.8	6.8	6.9
4	16 7.0	6.7	6.8	7.1	6.8	6.6	6.5	6.6
8	14 6.7	6.9	6.1	6.1	6.5	6.8	5.9	5.1 **
12	18 6.7	5.3 **	6.4	6.3	6.6	6.3 **	6.0	6.1
16	15 5.0 **	6.6	6.4	6.4	5.5 **	6.2	5.8	6.6
20	16 6.2	5.6 **	5.9	6.1	6.1	6.6 *	5.5 *	6.1
24	15 6.7	5.3 **	6.1	6.7	6.3	6.1 **	5.7 *	6.3
28	17 6.7	6.3	6.3	6.5	6.2	5.5	5.5 *	6.0
32	12 6.1 *	6.0	6.5	6.5	5.3 **	6.1	6.3	6.3
36	15 5.6 **	5.6 *	6.1	6.6	5.0 **	6.7	5.7	6.1
40	15 5.6 **	6.3	6.7	6.3	6.3 **	6.0	6.8	6.7
44	17 6.1	5.5 *	6.3	5.6 **	6.2	5.6	5.9	6.2 **
48	18 5.6 **	5.3 **	5.9	5.0 **	5.1 **	6.6 *	5.8	5.7 **

NOTE: All samples were rated on a 9-point scale in which 1 - extremely poor, 9 - excellent.

* - $p < 0.05$ Designation of significance refers to comparison of storage mean rating with initial rating for the same treatment.
 ** - $p < 0.01$ treatment.

RESULTS AND DISCUSSION

Storage Stability.

Table 1 shows the results of sensory panel evaluations of odor and flavor of the bacon samples at 4-week intervals over a storage period of 48 weeks at -18°C.

Initial mean panel ratings for odor for all products ranged from 6.5 to 7.0 ("good" quality). Mean panel ratings for flavor also rated as "good" quality, except for a panel rating of 5.8 for hardwood-smoked product packaged in air.

LS/VAC samples showed no significant change in odor quality throughout the 48-week storage period. However, flavor ratings of these samples at the 20-, 24-, and 28-week intervals were rated as "above fair" quality and were significantly lower (5% level) than the initial rating. Comments by panelists suggest that the downgrading in each instance was due to variability in sample composition and preparation, for example, "very salty", "off flavor", "slightly rancid", "overcooked", "lacks bacon flavor". This suggestion of sample variability is supported by the fact that, in each of the five subsequent intervals (32 through 48 weeks), LS/VAC samples were given flavor ratings that were not significantly different from the initial rating.

The HS/VAC samples received significantly lower ratings for both odor and flavor at the 16-week storage period, but this was followed by three consecutive storage periods (20, 24 and 28 weeks) of higher ratings, which were not significantly different from the respective initial ratings. Again, this difference may have been due to variation in sample composition. Four of the 15 panelists found the sample to be "rancid" to some degree and others found it to be "stale", "old", "off", etc. Odor and flavor ratings for samples evaluated at each of the five storage periods from 32 weeks through 48 weeks, with the exception of the 44-week interval, were significantly lower (1% level) than the initial ratings. Mean panel ratings for nearly all of these storage samples fell within the borderline quality range. Frequent comments of rancid flavor were made for samples from the 36-, 40-, and 43-week storage periods.

Odor and flavor ratings of all LS/AIR samples, except for flavor evaluated for 8 weeks storage, were consistently in the "good" to "below good" quality score range, but at the 44- and 48- week intervals became significantly lower (1% level) than the initial samples; these were in the borderline "fair" quality score range for odor, and "below fair" to "above poor" score range for flavor. At 8-weeks storage, the mean (5.1) for flavor of the LS/AIR bacon was significantly lower (1% level) than the initial rating (6.9) for the same treatment. Since ratings of bacon given this treatment at each of 8 subsequent storage intervals were consistently higher (ranging from 6.0 to 6.7) and not significantly different from the initial rating, it is considered most likely that this outlying rating occurred as a consequence of variability in composition (fat/lean) of the bacon. It should be noted, however, that of the 14 panelists involved in the test, seven commented that their sample had a rancid flavor note (3 slight, 4 moderate).

The HS/AIR samples had a lower initial mean panel rating (5.8) for flavor compared to the initial flavor rating given to each other treatment sample. Frequent comments by panelists indicated that the 5.8 quality rating was due to the presence of "stale", "salty", "off", and "rancid" flavor notes. A definite downward trend in flavor and odor ratings is evident from the 12th week of storage onward, with the exception of the 16-, 28- (odor only), 32- and 40-week intervals. Flavor and odor ratings for the 12-, 20-, 24-, 28- (flavor only), 36-, 44-, and 48-week periods were all "below fair" to "above fair" in the quality range. Panelist comments indicated that the downgrading was due to the presence of "rancid" and "off" odor and flavor notes.

In general, the storage stability data indicate that: (1) sliced bacon produced with liquid smoke and packed under vacuum (LS/VAC) retained "above fair" quality for odor and flavor throughout 48 weeks of storage, (2) liquid smoke bacon packed under air (LS/AIR) retained acceptable quality for odor and flavor only throughout 40 weeks of storage, (3) sliced bacon produced with hardwood smoke and vacuum-packed (HS/VAC) retained acceptable quality for odor and flavor only throughout 28 weeks of storage, and (4) hardwood smoke bacon packed under air (HS/AIR) showed significant loss of odor and flavor quality by the twentieth week of storage.

Comparison of Treatments (Hardwood Smoke vs. Liquid Smoke) and Packing Methods (Vacuum vs. Air)

Regression analyses were performed on the means in Table 1, to compare treatments-- Hardwood Smoke (HS) and Liquid Smoke (LS), and packing methods, vacuum (VAC) versus air (AIR). The data show no evidence of a lag or induction period; thus, linear regression analysis was deemed sufficient.

Figure 2 shows the four regression lines for odor: HS/VAC samples, HS/AIR samples, LS/VAC samples, and LS/AIR samples. Regression analysis shows the slope of the odor line for the LS/VAC samples to be not significantly different from zero; whereas, the HS/VAC, HS/AIR, and LS/AIR samples have negative slopes, significant at the 95% confidence level as estimated from a Student t-test.

The least squares analysis shows that for the odor attribute:

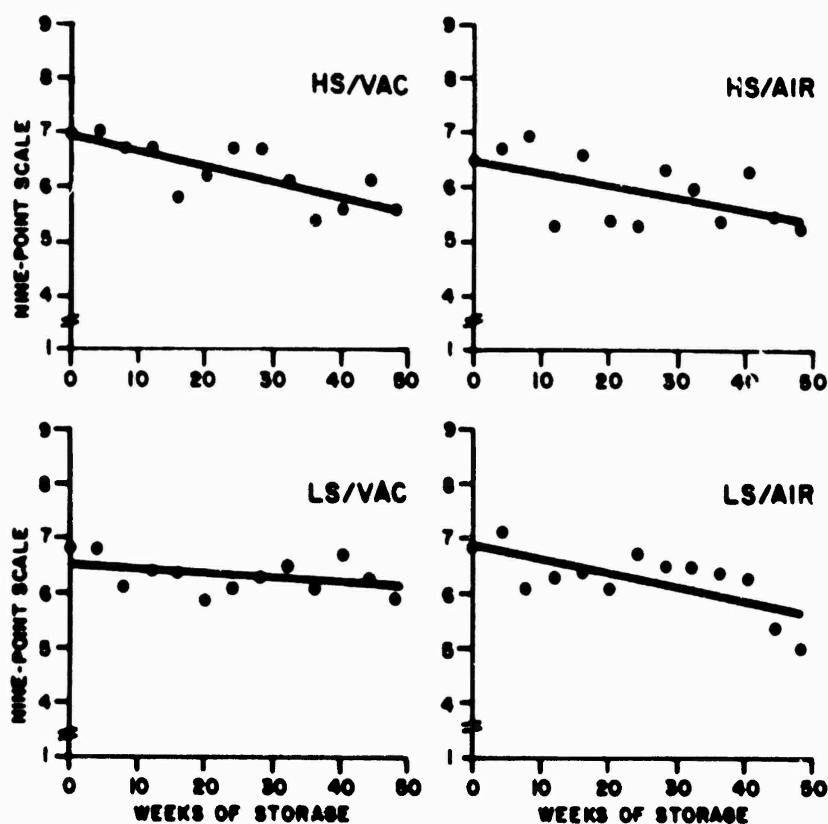
- (1) The LS/VAC samples were more stable than the HS/VAC samples, the HS/AIR samples, and the LS/AIR samples.
- (2) The LS/AIR and HS/AIR slopes are not significantly different from each other.
- (3) The HS/VAC slopes are also not significantly different from the LS/AIR and HS/AIR samples.

Figure 3 provides the four regression lines for flavor: HS/VAC samples, HS/AIR samples, LS/VAC samples, and LS/AIR samples. Regression analyses show the slopes of the flavor lines for the HS/AIR and for the LS/VAC samples are not significantly different from zero; whereas, the HS/VAC and LS/AIR curves have negative slopes.

The least squares analyses show that for the flavor attribute:

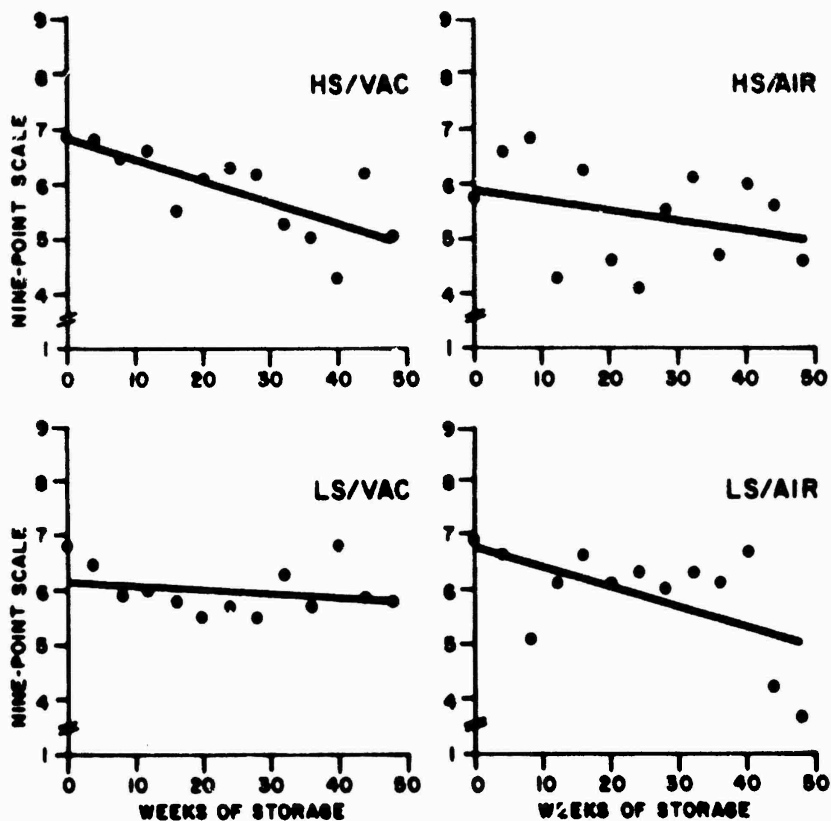
(1) The HS/VAC samples and the LS/AIR samples were not different from each other and were most changeable. The estimated shelf life of both sets of samples is 48 and 50 weeks. This is the predicted time at which the products would be judged below 5.0 (fair) in average flavor quality.

(2) The HS/AIR samples suffered from a great deal of variability which causes the slope estimate to be not significantly different from zero even though the slope estimate was not especially small.



Scale: 1 = extremely poor; 9 = excellent

Figure 2. Regression lines for mean sensory panel ratings for odor of sliced bacca produced with hardwood smoke (HS) or liquid smoke (LS) and vacuum (VAC) or air packed, evaluated at 4-week intervals over 48 weeks of storage at -18°C .



Scale: 1 = extremely poor; 9 = excellent

Figure 3. Regression lines for mean sensory panel ratings for flavor of sliced bacon produced with hardwood smoke (HS) or liquid smoke (LS) and - vacuum-(VAC) or air-packed (AIR), evaluated at 4-week intervals over 48 weeks of storage at -18°C.

CONCLUSIONS

1. Samples of sliced bacon, produced with liquid smoke and packed either under vacuum or under air and stored at -18°C , were found to retain mean ratings for odor and flavor of "above fair" quality for a longer period of time than did either comparably stored vacuum- or air-packed samples of sliced bacon produced with hardwood smoke.

a. Liquid smoke vacuum-packed sliced bacon samples retained "above fair" sensory quality (for odor and flavor) throughout the 48-week storage period.

b. Liquid smoke air-packed bacon samples retained "above fair" quality (for odor and flavor) for 40 weeks at -18°C before a significant drop in quality occurred.

c. Hardwood smoke vacuum-packed sliced bacon samples retained "above fair" quality for both odor and flavor for 28 weeks at -18°C .

d. Hardwood smoke air-packed sliced bacon showed significant loss for odor and flavor by the 20th week of storage.

2. For both smoke treatments, the vacuum-packed samples retained their "above fair" quality for odor and flavor for a longer period of time than did the air-packed samples.

RECOMMENDATIONS

1. It is recommended that Military Specification PP-B-81 be modified to prescribe a liquid smoke process in lieu of a hardwood process.

2. No change should be made in the requirement for vacuum packaging of sliced bacon procured for military use.

ADDENDUM

As a result of this study, Military Specification PP-B-81H was modified (Amendment-2, May 18, 1977) to permit use for production of cured smoked belly as follows:

"...Alternatively an aqueous solution, made from smoked hickory wood, suitable for surface application, may be substituted for wood smoke. The bacon shall be treated with liquid smoke either by spraying, atomization or regeneration method in accordance with 3.6..."

This document reports research undertaken at the US Army Natick Research and Development Center and has been assigned No. NATICK/TR-84/050 in the series of reports approved for publication.

REFERENCES

1. Military Specification PP-B-81G, Bacon, Slab or Sliced, Chilled or Frozen State.
2. R. G. D. Steel and J. H. Torrie, 1960. Principles and Procedures of Statistics., 1st Edition, McGraw-Hill.